STUDIES IN STREAM POLLUTION BIOLOGY

I. A Simplified Ecological Classification of Organisms

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Introduction

In recent years stream pollution investigations have been receiving increasing attention. With modern industrial expansion and increasing urbanization nationally, the need for greater conservation of our aquatic resources has become more obvious, due to shortages of water in some areas and destruction of the value of other streams by increasing pollutional loads. This need is being met with varying degrees of success by our federal and state agencies, and by an increasing awareness of their own responsibilities by public officials and by industry. In spite of greater activity with regard to the chemical and physical aspects of pollution investigation, biological data do not at the present time constitute a standard part of this work in many parts of the country. The reasons for this neglect of biotic data are not too hard to find.

Most stream pollution investigations are carried out or directed by engineers. While many of these engineers desire, or at least approve of, the use of biotic data, the ideas that such biological investigations are exceedingly complicated and prohibitively expensive are widespread. A brief review of the history of biological measurement of pollution will show why these ideas exist.

The works of Kolkwitz and Marsson (1908-1909) were pioneering studies in the use of aquatic organisms as indicators of the ecological conditions under which they exist. Organisms were classified as oligosaprobic, mesosaprobic and polysaprobic, depending on the concentration of decomposable organic matter in the streams under consideration.

Richardson (1921, 1925, 1925a, 1928) studied the organisms of the polluted Illinois River where he developed a classification of the bottom organisms using seven groups of species. These are as follows:

I. The pollutional group, which includes the Tubificidae and at least two species of midge larvae.

II. The sub-pollutional group, unusually tolerant subdivision. Included here are several each of the Sphaeriidae, leeches, midge larvae and Bryozoa.

III. The sub-pollutional group, unusually tolerant or doubtful subdivision. This category was set up for several doubtful species of midge larvae.

IV. The sub-pollutional group, less tolerant subdivision. This group included several species of midge larvae, Sphaeriidae, one gastropod, one leech, a few worms and a few young Unionidae.

V. Pulmonate snails and air-breathing insects.

VI. Current-loving species other than pulmonate snails and air-breathing insects.

VII. Cleaner-water species.

Major contributions to an understanding of the biotic effects of pollution were made by Lackey and summarized in his own report published in 1941.

The paper by Gaufin and Tarzwell published in 1952 is an excellent study of the utilization of aquatic invertebrates in stream pollution investigations. They employ both indicator species and indicator associations. Conclusion 5 (p. 64) states: "Pollutional associations are characterized by few species but large numbers of individuals." This is a fundamental concept in any classification of organisms with regard to decomposable organic pollutants in which a toxic effect is negligible.

Patrick (1949) bases her evaluation of stream conditions only on diversity of fauna and flora. Her study was the result of the work of Dr. Patrick, some twenty members of her staff, and twenty consultants. The total amount of information gathered by this group is great, but hardly within economic reach of the average state regulatory agency or industry, and the information obtained is not available to the general research worker.

Certain fundamental differences between the Gaufin and Tarzwell approach and that of Patrick are brought out in a recent article by Patrick (1953) and its accompanying discussion by Gaufin and Tarzwell. The most important differences are in the extent of survey work performed in the programs of these two groups of investigators. Patrick's methods suggest that the bio-dynamic cycle should be maintained in the primitive condition, while Gaufin and Tarzwell believe that this cycle may be altered to a major degree without destroying the value of a stream. Thus the methods of Gaufin and Tarzwell allow for equitable stream use, while any deviation from the primitive bio-dynamic cycle is interpreted by Patrick as evidence of pollution.

I had occasion to discuss the Gaufin and Tarzwell program with them while attending a training course at the research and training center at which they did their work, and I have made two surveys with Dr. Patrick and her staff. Both programs are consequently well known to me and are respected.

In the paragraphs above, some five programs for the biotic examination of streams have been outlined. Of these programs only one, that of Lackey, appears to be relatively simple and economical. Kolkwitz and Marsson attempted to classify all aquatic organisms with regard to degrees of pollution, a project that must have required the full-time service of an impressive array of biologists. The reports by Richardson cover work done by most of the staff of the Illinois State Natural History Survey, again a program that is too costly for most regulatory agencies. The Gaufin and Tarzwell program is simpler, but still one that uses four or five biologists. Patrick's surveying methods have received the most publicity and are consequently better known among state regulatory agencies than are the others. In this case the best known program is the most complex and costly one. The need for a simplified, economical program for the biological evaluation of stream condition is, therefore, a real one.

A number of writers have published shorter works with many valuable ideas and suggestions. Bartsch (1948) and Van Horn (1949) presented general ideas on the biotic response to various types and degrees of pollution. The paper published by Henderson in 1949 demonstrates the amount of biological information that might be gathered by one man using the Surber sampler.

The above and many other papers constitute a fairly extensive literature on the subject of stream pollution biology. A review of this literature indicated that a simple, yet adequate, program could be developed.

The present study began early in 1948 with chemical, biochemical and physical investigations of stream conditions in Florida. Biological work started in August, 1950, and has continued to the present. Thus two and one-half years were devoted to obtaining a general understanding of the chemical and physical aspects of pollution and stream behavior before any attempt was made to examine the biological conditions extant in Florida streams.

Setting up a biological program was accompanied by certain problems in the selection of methods and organisms. The methods selected should, of course, be effective, they should be economical, and they should not be too time-consuming.

The first consideration became the choice of method. As outlined above, there have been two main directions of investigation into the biology of stream pollution—the study of indicator organisms or a study of the diversity of fauna. It was felt that both viewpoints could be examined simultaneously, thus avoiding two separate lengthy studies. My employment by a state stream regulatory agency proved a major asset in that at least some information regarding the condition of every stream within the state was either in our files or could be obtained quickly. In the case of interstate streams such information could generally be obtained in a few days.

The selection of organisms required more careful consideration. Three groups of animals have been used in the past; the fishes, the plankton, and the macroscopic invertebrates (frequently referred to as "bottom organisms"). The fishes presented several problems which made them undesirable for this work. Their superior swimming ability enables them to cover significant distances in a brief period and possibly enables them to withdraw entirely from a polluted area; it is difficult for one man to collect a fair representation of the species present quickly; and storage of specimens rapidly becomes a problem.

Total plankton, or various elements comprising it, have been widely used in the past. My initial objection was that these organisms had received comparatively little attention in Florida and were virtually unknown. In addition, they are, by definition, at the mercy of currents and are, in essence, a moving fauna.

The macroscopic invertebrates were finally selected as biological indicators of ecological conditions for a number of reasons. As a group they are relatively well known in Florida. Faunal studies have been made of the Ephemeroptera, Odonata, aquatic Coleoptera, Trichoptera, Culicidae, aquatic Hemiptera, Tipulidae, crayfishes and sponges. Contributions have been made toward a knowledge of the molluscs, Plecoptera and Ceratopogonidae. Many of these organisms live in cases attached to immovable objects, burrow in the bottom of the stream or are vegetation dwellers. The aquatic life-histories are long enough in most cases to make the development of a fauna in a section of a stream a lengthy process. Ecological studies made of the aquatic invertebrates in Florida strongly indicate that definite response to environmental alterations, i.e., organic pollution in the present study, might be predicted. In addition, the number of species in some of these groups is not great.

It is probable that an adequate difinition of pollution has not been written. The following, inadequate though it may be, is used in this report. Pollution is the alteration of any body of water, by man, to such a degree that said body of water loses any of its value as a natural resource. This definition stems in part from the old English common law and the concept of riparian rights. It differs from most other definitions in the natural resource viewpoint. Water is unquestionably one of our truly important natural resources. If we may extend this last viewpoint somewhat and consider a stream as a resource, then a common sense approach to the subject of stream pollution abatement and equitable stream use is not difficult to reach.

Ecological Classification

There appears to be no simple classification of the streams of Florida. There are, however, definite categories of streams that exist as distinct types. Ecological distribution of the organisms discussed in this report will be considered in terms of these stream types.

The classification proposed by Rogers (1933) and modified by Herring (1951) has been followed. Herring recognized the following stream types in his study: calcareous, sand-bottomed, swamp-and-bog, and the larger rivers of mixed origin. In a sense this classification is simplified to an extreme degree. Actually there are all degrees of intergradation between any two of the above types.

Calcareous streams originate entirely, or to a major degree, from calcareous springs. These streams are of major importance in Florida which has seventeen springs of first magnitude (average flow of 100 second-feet or more), according to Ferguson *et al* (1947).

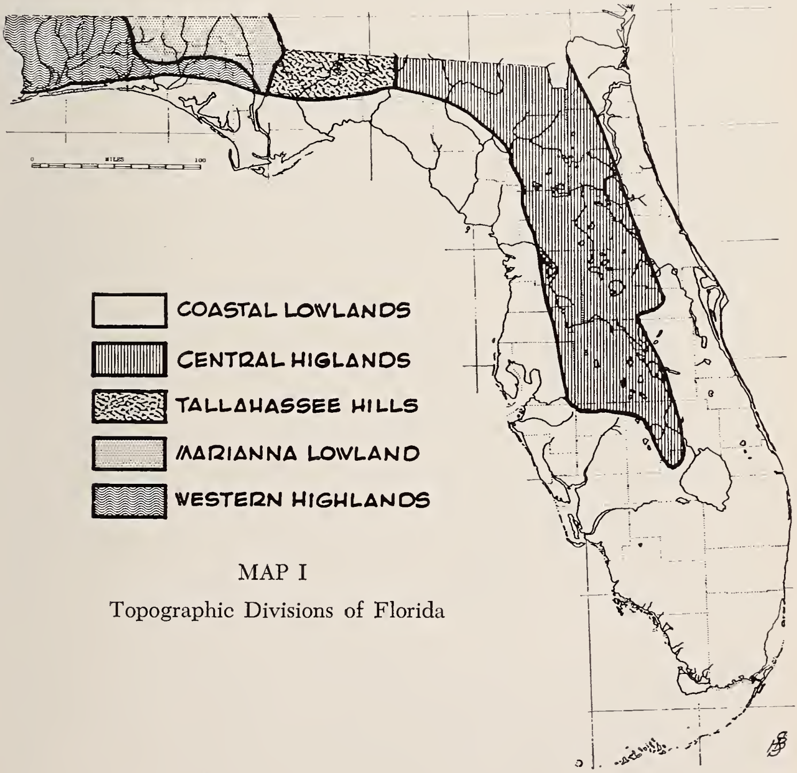
In addition, Florida has forty-nine springs of second magnitude (average flow 10 to 100 second-feet). The normal pH range for calcareous streams is 7.0 to 8.2, the alkalinity is generally high and is in the form of bicarbonate. The water is usually clear; the bottom composed of limestone, sand or clay, and plant growth may be slight to heavy. The calcareous stream is widely distributed in the state.

Sand-bottomed streams are fed by lakes, swamps or ground water from seepage areas. These streams are acid (pH 4.5 to 6.5), the water is soft and color is high. Bottom materials consist of sand, occasionally limestone, fine gravel and plant detritus in the quiet pools. Plant growth may be slight to heavy.

The swamp-and-bog streams are characteristically found in the Coastal Lowlands and are very similar in origin and chemistry to the sand-bottomed stream, the most significant difference being the higher velocity normally found in the latter stream type. In the case of the swamp-and-bog stream, flow is frequently imperceptible and the bottom may be of mud or very fine organic detritus. Organisms such as simuliid larvae, stonefly nymphs, or helgrammites, generally found in streams of at least moderate velocity, are seldom found in these swamp streams. The invertebrate fauna of this type of stream is more suggestive of a pond or swamp than of a stream. The pH of such a stream may range as low as 4.0.

The larger rivers of Florida are streams of diverse origin and behavior. Since this report does not encompass a study of stream types and origins, only one of these rivers will be discussed here. As an example of a larger stream, the Suwannee River originates in the great Okefenokee Swamp of southern Georgia. Near the Georgia-Florida line, this river has the characteristics of a swamp-and-bog stream with dark, sluggish, acid (pH 4.2) water. A few miles downstream, however, the gradient increases, the stream bed is composed of Ocala limestone and sand, the pH increases to over 5.0, and the river has become essentially a sand-bottomed stream. Downstream from this section of the river the first of a large number of calcareous springs discharges into the stream. The combined effects of the addition of spring water and the solution of limestone in the bed of the river convert the Suwannee into a calcareous stream within comparatively few miles. Thus all three stream types discussed above may be found in the same stream within a few miles of its length and the main stream has to be classified as yet a fourth type because of its complex origin and unusual behavior. In the Suwannee, variation in discharge is accompanied by most significant variations in water chemistry.

The above discussion points out but a few of the problems involved in classification of the streams of Florida. In the Coastal lowlands and the Central Highlands the acid characteristics of the sand-bottomed stream appear to be derived from organic sources (humic acid, humates, etc.), while in the Western Highlands there are streams (within the defined limits of the sand-bottomed stream) in which the acidity appears to be from an inorganic source. All this merely means that a great deal more work needs to be done in the field of fundamental limnology in Florida.



MAP I

Topographic Divisions of Florida

Geographic distribution of organisms is reported by topographic divisions described by Cooke (1939). Cooke (p. 14) writes: "The part of the Floridian Plateau that lies above sea level—the State of Florida—is divisible into five natural topographic regions: the Coastal Lowlands, or more recently emerged region, which almost everywhere lies less than 100 feet above sea level; and the interior, generally higher, hilly regions, consisting of the Western Highlands, the Marianna Lowlands, the Tallahassee Hills, and the Central Highlands." The generalized outlines of these regions are shown on map I. The tabulation of distribution of organisms in these regions showed such complete distribution that the table seemed pointless and was consequently omitted.

Most of the organisms reported on in this paper are present in the streams throughout the greater part of the year and collections made during the winter months are fully as significant as are summer collections.

METHODS

The actual mechanics in the establishment of the program involved sampling streams of known pollutional condition. This included streams which received no domestic or industrial wastes, as well as streams exhibiting varying degrees of pollution. It was decided that a given organism must be present in a minimum of twenty collections before any attempt would be made to examine the records with regard to the proposed classification. This was an arbitrary figure which appeared to me to be high enough to represent a significant ecological and geographical distribution and small enough to permit a reasonably lengthy list of organisms to be obtained in a short time. It should be noted that these collections were not made in any definite sequence. In other words, the organisms were not collected from clean streams alone, but streams in all conditions with regard to organic pollution, as well as various rates of flow, were sampled as they were encountered. Such collections were made while I was conducting chemical or bacteriological surveys, with an occasional short period devoted to biological work alone. These collections were obtained for a period of a year before any attempt was made to develop a classification. By that time, approximately two hundred collections had been made. The present paper, with but minor revisions in the initial classification, is based on the study of five hundred collections and an estimated fifty thousand organisms.

General stream collecting methods are used in securing the biological samples. I normally use a dip net, Eckman dredge, coffee strainer, potato fork and a series of shallow, white-enamelled pans. Care must be taken that the various habitats within the area selected are examined and a representative collection obtained. It is more difficult to obtain a reliable collection from a polluted area than from a clean one because the collector must be certain that the more sensitive forms were actually lacking and not merely overlooked due to haste. This is particularly obvious when one considers that the methods here presented are directed toward proving that an area is clean and that inability to do so constitutes evidence of pollution.

An actual survey using these methods begins with the selection of stations with regard to the actual or eventual introduction of waste materials into the stream. Such stations should also be typical of the stream in general and should be readily accessible.

Following careful and representative collecting at all stations in the survey, the material is separated and identified as accurately as possible by the collector. Classification with regard to organic pollution follows next. Certain organisms, tentatively identified by me, are then forwarded to specialists in the various groups represented for final identification.

Essentially all the material collected in these surveys is saved and eventually is sent to private collectors or to museums.

INDICATOR ORGANISMS

As indicator organism is a plant or animal, the presence or absence of which is indicative of some fact or facts with respect to its environment. When the environment is altered by organic pollution both the fact of pollution and the degree of pollution logically should be demonstrable by the use of indicator organisms which have been properly selected.

In the classification of organisms, I decided against the use of a terminology derived from Latin or Greek (as in the Kolkwitz and Marsson system). Such a terminology must be carefully defined and would be most difficult to interpret in view of the complexity of pollution. In addition, most of my reports are submitted to engineering personnel who consider such terminology so much double-talk.

In this study I have divided the aquatic invertebrates into five numbered classes, of which only the first three are important in the reporting of stream conditions. The remaining two classes are categories of convenience, as will be pointed out below.

Class I is comprised of those organisms which have been found to tolerate no appreciable organic pollution, the more sensitive forms. The presence of Class I organisms is considered indicative of the fact that the water in which they are found is clean.

Class II organisms are those which tolerate a moderate amount of pollution, but do not tolerate conditions approaching or reaching the anaerobic. Thus the presence of Class II organisms may be interpreted to mean that the area in question is not heavily polluted.

Class III contains organisms which have been found in heavily polluted areas. It should be understood that no organism in Class III may be considered indicative of pollution. These organisms may be found in clean waters, moderately polluted waters, or grossly polluted waters.

Class IV includes organisms independent of dissolved oxygen—the air breathing forms. In this category are the Hemiptera, most larval and adult Coleoptera, Culicidae, Syrphidae, Tipulidae and pulmonate snails. Since the first effect of an organic waste on a body of water is a reduction in dissolved oxygen content, it seemed that these independent organisms might be placed in a separate category and the time saved could more profitably be devoted to organisms that were closely attached to the aquatic habitat. This does not mean that all the organisms in this classification would of necessity respond similiarly to environmental alteration due to organic pollution. Molluscs of the genera *Physa* and *Ferrissia* are listed under Class III due to their frequent occurrence in collections and their demonstrated ability to survive high degrees of pollution.

Class V comprises those organisms which have not been otherwise classified due to such factors as too few records, lack of knowledge of their physiological requirements, or organisms for which identifications are pending. This class is in essence the reservoir from which future representatives of the first three classes will be derived.

Table I lists the number of records for each of the organisms comprising classes I, II, and III with reference to the three degrees of pollution recognized in this study. Examination of this table naturally raises the question as to the level of identification at which significant indicator value is found. Certainly specific determinations are the most desirable. Florida, however, is still a pioneer area with regard to the taxonomy of many of the groups of organisms which I collect. The genus *Asellus* is an interesting example of the taxonomic problems involved. All specimens of this genus (with the exception of damaged specimens) thus far sent to Dr. Mackin have been determined to species, but there are three species for which only manuscript names are available. In the case of the stoneflies, reporting in this paper is done at the level of order, although all specimens are identified to species. Dr. Gaufin and I have been working on the nymphs of this order for the past eighteen months and the study is quite incomplete. The widely distributed mayfly genus *Stenonema* was used as an indicator organism at generic level before enough records were available to make specific identifications significant. The genus then yielded three Class I species (*exiguum, smithae* and *Stenonema* spp., this last including *proximum* and an unknown species). In the case of the damselfly *Argia,* seventy-two records were available before the nymph was even classified.

When at least twenty records for a Class V organism are present each record is examined carefully. If the organism has been found only in clean waters, it is placed in Class I. If, however, a single record is from a moderately polluted area the organism falls in Class II, just as a single record from a heavily polluted area places the organism in Class III.

During a recent discussion of this classification, it was suggested that if a single record may bring about the transfer of a species from a cleaner to a less clean class, eventually all organisms would become Class III. While the suggestion appears quite logical, there has been little in practice to indicate that such is the case. During the nearly three years that this classification has been in use, only two Class I organisms have been lowered to Class II and none from either I or II to III.

It is probable that eventually a statistical scale for the classification of these organisms may be called for. A suggestion of the usefulness of such a scale may be found in Table I. Of a total of seventy records for *Palaemonetes paludosus,* four are from moderately polluted areas, while of sixty-eight records for *Oecetis* spp. only one is from a moderately polluted area. It would thus appear that *Palaemonetes* would more probably be found in an area of moderate pollution than would *Oecetis,* and that the former is a more reliable member of Class II than is the latter. A statistical scale may be suggested as a future refinement, but does not enter into the present interpretation of results.

TABLE I

Pollutional Distribution

Organism	Clean Water	Moderately Polluted Water	Highly Polluted Water	Total Number Records	Class
Oligochaeta	191	10	9	210	III
Asellus spp.	85	0	0	85	I
Hyalella azteca	87	6	0	93	II
Palaemonetes paludosus	66	4	0	70	II
Hydracarina	73	0	0	73	I
Plecoptera	61	0	0	61	I
Stenonema exiguum	58	0	0	58	I
Stenonema smithae	62	0	0	62	I
Stenonema spp.	46	0	0	46	I
Gomphus pallidus	48	3	0	51	II
Gomphus spp.	27	1	0	28	II
Progomphus spp.	40	0	0	40	I
Macromia spp.	39	3	0	42	II
Argia spp.	72	0	0	72	I
Corydalis cornutus	87	0	0	87	I
Oxyethira spp.	36	0	0	36	I
Hydroptila spp.	31	0	0	31	I
Macronemum carolina	21	0	0	21	I
Hydropsyche incommoda	36	0	0	36	I
Hydropsyche spp.	40	0	0	40	I
Cheumatopsyche spp.	119	2	0	121	II
Polycentropus spp.	72	0	0	72	I
Oecetis spp.	67	1	0	68	II
Leptocella spp.	49	2	0	51	11
Chimarra spp.	76	0	0	76	I
Pyralididae	38	0	0	38	I
Simuliidae	89	0	0	89	I
Pentaneura nr. *monilis*	83	2	2	87	III
Pentaneura flavifrons	26	0	0	26	I
Tanypus stellatus	4	2	2	8	III
Corynoneura spp.	70	0	0	70	I
Spaniotoma spp.	35	1	0	36	II
Tanytarsus exiguus	42	0	0	42	I
Tanytarsus gregarius	32	0	0	32	I
Polypedilum fallax	28	1	0	29	II
Cryptochironomus spp.	64	4	2	70	III
Cryptochironomus sp. B. (Joh.)	21	0	0	21	I
Chironomus decorus	60	5	6	71	III
Chironomus spp.	14	3	3	20	III

It should be pointed out that only organisms from Classes I, II and III have been listed in the table. Since the other two classes have little immediate importance in these proposed methods, there seems to be no reason for needless tabulation.

TABLE I (Continued)

Pollutional Distribution

Organism	Clean Water	Moderately Polluted Water	Highly Polluted Water	Total Number Records	Class
Ceratopogonidae	109	5	1	115	III
Physa spp.	98	7	5	110	III
Ferrissia spp.	71	4	2	77	III
Goniobasis spp.	45	0	0	45	I
Sphaeriidae	106	5	1	112	III

DISCUSSION

Indicator Organisms

The group of organisms comprising Class III merits some discussion despite the fact that the presence of these forms indicates little regarding the quality of the water. Although certain of the chironomid larvae and the tubificid worms may be passed over hastily with regard to existence under anaerobic conditions the same does not hold true for nymphs of the mayflies *Callibaetis floridanus* and *Caenis diminuta,* nor for one unidentified damselfly nymph. Their ability to survive in waters containing no dissolved oxygen is unexplained, though real.

As stated above, a reduction in dissolved oxygen is the first effect of an organic pollutant. Thus dissolved oxygen is of primary importance in stream quality investigations. Modifications of the Winkler method for the determination of dissolved oxygen give very accurate results for a simple and rapid analysis. There are, however, many variables which must be taken into consideration when interpreting dissolved oxygen figures. Corrections for factors such as temperature, barometric pressure and salinity may be applied by use of tables or nomographs which may be found in many books and shorter publications. Factors such as algal blooms and natural pollutional effects which influence the oxygen concentration must be evaluated by other methods. It will thus be seen that dissolved oxygen may not be used as a single measure of stream condition with any reliability.

Pure water is not found in streams. A stream without dissolved solids and gasses would be sterile due to lack of nutrients for the lower organisms at the base of the food chain. If one wished to take an extreme viewpoint he might consider the addition of any solid, liquid or gas to a body of water as pollution. In a sense this is true, and the concept of natural pollution must be considered in any evaluation of stream condition. It is not proposed in the present report to discuss the subject of natural pollution at any great length. Special work on this subject is being carried on at present by the Florida State Board of Health and will be reported on at a later date. It will suffice to say here that natural pollution does not interfere with the use of the methods outlined in the present report.

The following excerpts are from Gaufin and Tarzwell (1952:62): "In evaluating aquatic organisms as indicators of pollutional conditions, great caution must be used because of several complicating ecologic conditions. First, many organisms which occur in extremely polluted water may also be found in limited numbers in cleaner situations. Several species of invertebrates, such as the mosquito, *Culex pipiens;* beetle, *Tropisternis* spp.; and sludgeworms, *Limnodrilus* and *Tubifex* spp., which occurred in abundance at Stations 6.5 and 5.2 [polluted waters] also occurred in the clean-water zones. Second, many species listed in Table 2 occurred in such small numbers as to discourage their individual use as indicators. Third, several ecologic factors other than the presence of a pollutant may limit the distribution of certain species; for example, erosion, floods, the size of the stream, the type of bottom, the flight range of the insect, and the portion of the stream under study. It is believed that moderate abundance of single species should not be considered as biological indicators of pollution because organisms such as *Tubifex* usually associated with polluted areas are also found in clean waters. It is the complex or association of organisms which is important for indicating clean or polluted water. All organisms present and their relative abundance must be considered."

Under the first qualification in the above quotation, the four genera listed are members of Classes III and IV in the present study and need not prove deterrents to the use of indicator organisms.

Rare or uncommon organisms would be listed in Class V and would thus not prove misleading. The third factor listed by Gaufin and Tarzwell can hardly be answered briefly. It must be assumed that the person performing such a survey will be an aquatic biologist with a reasonable knowledge of stream ecology.

A review of the literature of stream pollution biology will show that indicator organisms may be used basically in two ways—to indicate the presence of pollution or to indicate the absence of pollution. If an attempt is made to establish a program utilizing the macroscopic invertebrates and based on the concept that there are such organisms which by themselves indicate pollution, then it is my belief that the program must fail. No macroscopic invertebrate has been found in Florida which, by itself, indicates pollution. On the other hand, an effective indicator organism program based on species which indicate absence of pollution can be developed quite easily. I am in complete agreement with Gaufin and Tarzwell when they say that the complex or association is of greatest importance as an indicator of stream conditions.

Diversity of Fauna

In the introduction it was stated that two approaches to this program were to be examined simultaneously—indicator organisms and diversity of fauna. The latter approach was abandoned for one main reason. It became apparent after careful examination of many of the streams of Florida that diversity of fauna was primarily the result of one factor—the diversity of habitat. Studies of the nutrient content of Florida waters have lagged seriously behind studies of other factors, primarily due to the lack of accurate and simple field methods for the quantitative determination of these nutrient elements. It seems probable, however, that above certain limits, the nutrient content would exert a quantitative rather than a qualitative effect on the biotic association.

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SUMMARY

A simplified method for the biological detection and measurement of organic pollution is presented. This method utilizes indicator values for selected macroscopic invertebrates. These values are determined by prolonged sampling of waters of known condition with regard to organic pollution.

The methods herein described will enable one man to obtain significant biological data with rapidity and economy. With certain faunal revisions these methods may be adapted easily for use in other geographical or political areas.

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